0038-075X/82/1334-0232$02.00/0
SOIL SCIENCE

April 1982
Vol. 133, No. 4
Printed in U.S.A.

EFFECT OF WATER MANAGEMENT AND BED HEIGHT ON SUGARCANE YIELD[1]

C. R. CAMP

U.S. Department of Agriculture, Agricultural Research Service, Coastal Plains Soil and Water Conservation Research Center, Florence, South Carolina 29502

Received for publication 25 November 1980; revised 16 June 1981

ABSTRACT

We determined the effect of two bed heights (flat or raised) and three water management regimes on sugarcane yield in a 3-year experiment on Mhoon silty clay loam soil in Louisiana. Annual rainfall during the 3-year period varied from moderately light to extremely heavy. Yield was not adversely affected when sugarcane was planted flat, but yield trends during wet years indicated a need for subsurface drainage or water table control. During the dry year, yield was higher for sugarcane planted flat than for that planted on raised beds. Sugarcane yields were significantly higher for subsurface drained treatments during the wet years and for the high, constant-water-table treatment during the dry year. Water management systems able to maintain water tables over a range of depths (0.3 to 1.5 meters) should provide maximum sugarcane yields. The water table depth required at a specific time would depend primarily upon rainfall.

INTRODUCTION

Sugarcane in Louisiana is usually planted on beds about 0.3 m above the bottom of the water furrow and spaced 1.8 m apart. Raised beds have been used since sugarcane was introduced to the area, primarily to provide adequate drainage and soil aeration in the soil zone where the seed cane is placed and the primary root system develops. Sugarcane grows actively for about 7 mo, from April through October (Matherne et al. 1972). Mean annual rainfall varies from 135 to 160 cm in the sugarcane-producing area of the state, with a fairly even distribution throughout the year. Consequently, rainfall that occurs during the period when sugarcane is semidormant (November to March) is high in relation to evapotranspiration, exceeding plant requirements and often exceeding soil storage capacity. The soils in the sugarcane area of the state are medium- to fine-textured alluvial deposits along the Mississippi River and have moderate to low hydraulic conductivity values. The combination of excessive rainfall and slowly permeable soils causes high, perched water tables and poor aeration in many of the soils, particularly during the dormant season.

[1] Contribution of the USDA, Agricultural Research Service, Baton Rouge, Louisiana, in cooperation with the Louisiana Agricultural Experiment Station, Louisiana State University, Baton Rouge, Louisiana.

Sugarcane is a perennial that is propagated commercially by planting whole stalks. On the U.S. mainland, three crops of sugarcane are normally obtained from each planting (plant, first ratoon, and second ratoon). Sugarcane is usually planted from August to October, and the first crop is harvested the following autumn (Matherne et al. 1972).

Good surface drainage has long been recognized as necessary for the production of sugarcane in Louisiana (Stubbs 1895; Wasson and McCrory 1949). More recently, lowering the water table through the use of subsurface drains increased sugarcane yield and improved stubble longevity, so that the number of crops obtained from a single planting was increased from three to five (Carter and Floyd 1971, 1973). Carter and Floyd (1975) also found that lowering the water table during the winter, when the sugarcane is dormant, increased yield of the subsequent crop.

For further increase in sugarcane yield, improvement in energy efficiency, and reduction in production cost per unit of sugar produced, recent efforts have been devoted to increasing plant population through the use of closer row spacing (Irvine et al. 1980). As row spacing decreases, the soil volume available to form beds also decreases. Consequently, with narrower rows the height of the bed must be decreased significantly or the bed eliminated entirely, with the sugarcane being planted in furrows opened in a flat soil surface. This requires that the seed cane and subsequent root system be much closer to the water furrow and water table, if one exists in the soil profile, than when the row is located on a bed. Consequently, improved soil internal drainage could be much more important for the flat-plant system than it is for the bed system. Saveson (1956) showed increased sugarcane yields and decreased operating costs for flat planting over bed planting on precision-graded land for a study including two locations over a 6-yr period. Higher yields were obtained with better drained, medium-textured soils than with poorly drained, fine-textured soils. Reduced operating costs resulted from reduced drain maintenance and lower cultivation costs because of shallower cultivation, which required less power and was more adaptable to multirow equipment. Studies during 1928–30 showed that increased yields could be obtained with flat planting on ungraded land, but shallow cultivation did not provide adequate weed control, and chemicals to provide control were not available at that time (Taggert 1956, personal communication, as cited by Saveson 1956).

The objective of this study was to determine the effect of two bed heights above the water furrow on sugarcane yield for three different water-management regimes.

MATERIALS AND METHODS

The study was initiated in 1973 on a site of Mhoon silty clay loam located on the Louisiana State University (LSU) Ben Hur Research Farm. Eighteen plots, each about 40 m^2, were used for this experiment. Twelve plots with concrete borders extending from 0.3 to 1.5 m below the soil surface were used for the two drainage treatments in which the water table was controlled. Each of these plots contained two subsurface drain lines connected to a structure for controlling the water table level in the plot. The concrete borders and drain lines were installed in 1965; there had been no further soil disturbance since installation. The remaining six plots were not bordered and did not have subsurface drainage. Consequently, the water table in these plots fluctuated naturally in response to rainfall. Because the plots where the water table was controlled had concrete borders extending well below the water table, they did not affect the water table level in the fluctuating water table plots. Five sugarcane rows about 7 m long were planted in each plot. The width of the concrete-bordered plots allowed only three rows to be located completely within the borders, but one additional (border) row was located on each side of the plots near the concrete border. The three water-management treatments were (1) subsurface drained, with the water table at least 1.5 m below the soil surface; (2) water table maintained constant at 0.3 m below the soil surface by adding or removing water in the control structure; and (3) water table variable, fluctuating in response to rainfall, and no subsurface drainage provided. The two bed height treatments were (1) planting furrow opened in flat soil surface and (2) planting furrow opened in beds 0.3 m high. In both cases the planting furrow was about 0.2 m deep. A randomized complete block design with three replicates was used in both the 12- and 6-plot sections. Land preparation for planting included disking, precision grading, subsoiling about .45 m deep, and disking. In Treatment 1 (planting in flat soil surface), planting furrows were prepared in a flat soil surface with a conventional middlebuster. After planting, the seedcane was covered with about 5 cm of soil, which was compacted slightly to provide good seed-soil contact. A slight water furrow was created in the process of covering the seed cane. In Treatment 2 (planting on a raised bed), raised beds were prepared using disk choppers. Planting furrows were then opened on top of the beds using a conventional middlebuster. After planting, the seed cane was covered and compacted as in Treatment 1. The water furrow created in the process of preparing the raised bed was deepened slightly in the process of covering the seed cane. Consequently, water furrows existed in both treatments, but they were much deeper in the raised-bed treatment. Because of the elevation difference between the raised beds and the normal soil surface, the elevation of the seed cane in Treatment 2 was about 12 cm greater than that of the seed cane in Treatment 1. Therefore, the seed cane (and subsequent root system) in Treatment 1 was about 12 cm closer than the seed cane in Treatment 2 to the constant water table, which was maintained 0.3 m below the mean (original) soil surface. All plots were planted to sugarcane by hand in October 1973 with heat-treated seed (stalks), interspecific hybrid variety CP 65-357. Fertilizer was applied according to soil test results and recommendations of the LSU Soil Testing Laboratory. Standard pest control practices recommended by the Louisiana Cooperative Extension Service were followed throughout the study. All treatments were cultivated similarly with disk choppers, except that minor adjustments were made to allow for the difference in bed height. Because of cultivation and the deepening of the water furrow, the height of the seed cane above the water furrow changed with time. Elevations of the seed cane, top of bed, and water furrow were determined each year for both bed-height treatments to calculate the height of the seed cane above the water furrow.

The water table in the constant-water-table treatment (No. 2) was maintained at 0.3 m below the mean soil surface by automatically controlling the water elevation in the control structure. Water was added by a float-controlled valve on a pressurized water supply line whenever the water elevation dropped below a preset elevation. Conversely, excess water was removed from the structure by an overflow device. Water table elevations were measured in individual plots at least weekly, and the controls in the corresponding structure were adjusted accordingly to obtain the desired water table elevation in the plot. Adjustments were required primarily when rainfall patterns changed significantly, so that the system was required to move from an alternating mode (removing-adding water) to one that was either continually removing water or continually adding water.

Sugarcane was harvested by machine in November each year. The harvester base-cutter height was adjusted individually for each bed height to maintain a constant cutting height relative to the top of the bed. The harvest from the center three rows of each plot was weighed for yield determination. A 10-stalk sample was collected from each plot for sucrose and purity analysis in the laboratory and for determining sugar per ton of cane by the procedure described by Legendre (1976). Sugar yields obtained with these results are theoretical; commercially recoverable sugar yields are about 83% of the theoretical yields reported here. Plant population was determined each year at harvest. Rainfall was recorded on site with a recording rain gauge. All data were analyzed statistically by analysis of variance to determine treatment effects and interactions. Differences among treatment means were determined by use of Tukey's honest significant difference (hsd) procedure (Steel and Torrie 1960).

RESULTS AND DISCUSSION

Measurements taken each year to determine the height of seed cane above the water furrow show that the mean seed height differences between the flat and bedded treatments were 11.6, 10.7, and 11.0 cm, respectively, in 1974, 1975, and 1976. Seed height above the water furrow increased for all treatments each year because of cultivation, which moved soil from the furrow to the row. Although the flat-planted treatments were initially flat, a slight bed developed with cultivation.

Rainfall frequency and amount varied during the 3 yr of this experiment, providing distinctly different soil water regimes. Rainfall during 1974, 144 cm (Fig. 1), was near the long-term average (137 cm). Rainfall caused the water table in the variable water table plots to rise to within 0.3 m of the soil surface during January and February. As the sugarcane initiated growth in March and April, the water table gradually dropped until June and July, when it quickly dropped to a depth of about 1.2 m. Rainfall late in July and during August and September caused the water table to rise again to the 0.3- or 0.4-m depth. After a water table drop in October and the sugarcane harvest in November, the water table returned to within 0.3 m of the soil surface.

Rainfall in 1975, 180 cm, was 43 cm above normal; it occurred primarily during the spring and summer (Fig. 2). The water table in the variable-water-table plots was high (.15 to .45 m) almost continuously from January to August, when it dropped to moderately low levels until after harvest. Rainfall during the second ratoon

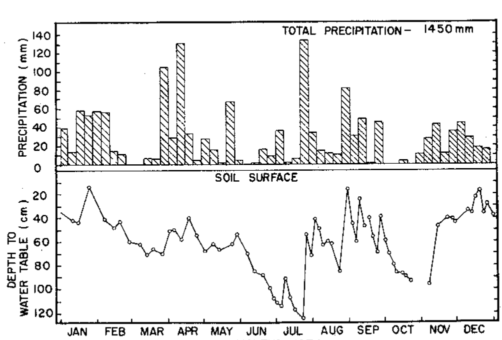

FIG. 1. Precipitation and water table depth for Mhoon sicl soil on the variable-water-table treatment during 1974 when rainfall was near normal.

crop (1976), 119 cm (Fig. 3), was slightly (18 cm) less than normal. Rainfall caused the water table in the variable-water-table plots to remain relatively high (0.3 to 0.6 m) from January through March, when it began a steady decline. The water table remained low (1.2 to 1.4 m) from August through October. After harvest in November, the water table again rose to a higher level, characteristic of the winter months.

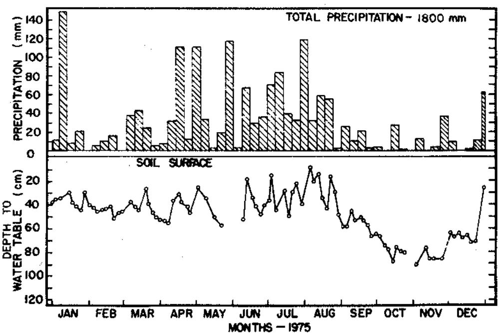

FIG. 2. Precipitation and water table depth for Mhoon sicl soil on the variable-water-table treatment during 1975 when rainfall was above normal.

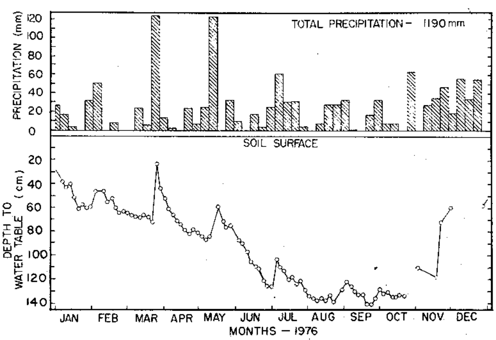

FIG. 3. Precipitation and water table depth for Mhoon sicl soil on the variable-water-table treatment during 1976 when rainfall was below normal.

Sugarcane yields for the various water table and bed height treatments were not significantly different for the plant crop in 1974 when near-normal rainfall occurred (Table 1). Sugar yield was significantly higher for the constant-water-table treatment than for the drained (low-water-table) treatment. Sugar yield for the variable-water-table treatment was intermediate between the other two water table treatments and was not significantly different from either. Similarly, the plant population for the constant-water-table treatment was highest, but was significantly different only from the variable-water-table treatment.

The plant population and sugarcane and sugar yield were significantly higher for the drained (low-water-table) treatment than for the other two water table treatments for the first ratoon crop in 1975 when above-normal rainfall occurred (Table 2). Although there was no significant difference in sugarcane or sugar yield due to bed height, the plant population for the bedded treatment was significantly higher than that for the flat-planted treatment. There were no significant interactions between the water table and bed height treatments. The yield increase for the drained treatment was undoubtedly due to improved internal soil drainage, which provided better soil aeration and a greater storage volume for the excess rainfall.

The constant-water-table treatment did not remain precisely constant during some periods of the 1975 growing season because of heavy

TABLE 1

Plant population, sugarcane yield, and theoretical sugar yield for the plant crop (1974)

Water table depth	Plant population, stalks/ha			Sugarcane yield, t/ha			Theoretical sugar yield, kg/ha		
	Flat	Bedded	Mean	Flat	Bedded	Mean	Flat	Bedded	Mean
Constant (0.3 m)	91 400	93 200	92 300a[a]	88.7	89.0	88.8a	8880	8700	8790a
Drained (1.5 m)	85 000	88 700	86 800ab	82.5	78.3	80.4a	7600	7050	7320b
Variable	80 800	86 700	83 800b	84.3	81.3	82.8a	8790	8120	8460ab
Mean	85 700c	89 500c		85.2c	82.9c		8420c	7960c	
HSD_{05}			6700						1300

[a] In a column or row, means followed by the same letter are not significantly different at the 5% level, according to Tukey's HSD procedure.

TABLE 2

Plant population, sugarcane yield, and theoretical sugar yield for the first ratoon crop (1975)

Water table depth	Plant population, stalks/ha			HSD_{05}	Sugarcane yield, t/ha			Theoretical sugar yield, kg/ha		
	Flat	Bedded	Mean		Flat	Bedded	Mean	Flat	Bedded	Mean
Constant (0.3 m)	73 400	73 600	73 500b[a]		63.2	63.9	63.6b	7720	7070	7400b
Drained (1.5 m)	80 100	83 800	81 900a		81.6	77.3	79.4a	10 000	9260	9630a
Variable	66 200	77 600	71 900b		58.3	63.0	60.6b	6790	7440	7120b
Mean	73 200c	78 300d		4700	67.7c	68.1c		8170c	7920c	
HSD_{05}			6900				11.6			1210

[a] In a column or row, means followed by the same letter are not significantly different at the 5% level, according to Tukey's HSD procedure.

rainfall and the relatively low storage volume in the soil. Water table data (Fig. 2) reflect the effect rainfall had on the naturally fluctuating water table. Similar activity occurred in the constant-water-table treatment, but to a lesser extent, for drain lines were present to remove the excess water. For example, on 3 July 1975, the water table in one of the constant-water-table plots was .13 m above the desired level as a result of 0.3, 0.8, and 3.5 cm of rainfall on 1, 2, and 3 July, respectively. Because of additional rainfall, the water table in this plot was 0.07 m above the desired level on 7 July and remained there until 18 July when it dropped to 0.02 m below the desired level. Similar fluctuations occurred after rainfalls of 2 to 5 cm or after lesser daily rainfall that occurred consecutively over a period of several days. The water table in the drained treatment fluctuated little or none except after heavy rainfall. When the water table did fluctuate, it returned to normal much more quickly than did the water table in the constant-water-table treatment.

Sugarcane yield, sugar yield, and plant population were all significantly higher for the flat configuration than for the bedded configuration for all water table treatments during the second ratoon crop in 1976 when below-normal rainfall occurred (Table 3). There was no significant difference due to water table treatment in any of the population or yield components, nor were there significant interactions between bed height and water table treatments. Additionally, the yields obtained for the second ratoon crop were as high as those obtained for the plant crop; yield for the ratoon crops normally declines from that of the plant crop.

The explanation for the higher yield obtained for the flat-planted treatment during the second ratoon crop is not readily apparent. The trend for the flat-planted, constant-water-table treatment to yield considerably more sugar than other treatments indicates the possibility that additional water was available to these plants due to the proximity of the root system to a constant water supply throughout the season. Because rainfall was much below normal for the year, less soil water was available during the growing season in the other water table treatments.

With the variable rainfall patterns that existed for the 3 yr of this study, it is not surprising that distinctly different results were obtained for each of the 3 yr. When rainfall was above normal (1975), the drained treatment (low water table) produced the highest yield, with no difference in yield due to bed height. When rainfall was near or below normal (1974 and 1976), either sugar yield did not differ (1976) with water table treatment or the constant-water-table treatment produced a higher yield than the drained treatment (1974). For these normal-to-dry years, sugar yield did not differ with bed height in 1 yr (1974) and was significantly higher for the flat-planted treatment in the other year (1976). Responses of sugarcane to the two bed heights during the wet year did not differ, except for plant population. This indicates that bed height may not be critical as long as subsurface drainage is provided or the soil profile drains naturally to a depth of 1 to 1.5 m.

The constant-water-table treatment used in this study was not as severe a treatment as could have been provided or as could exist under some field conditions. A high, fluctuating water table was found to be more damaging to plant roots

TABLE 3

Plant population, sugarcane yield, and theoretical sugar yield data for the second ratoon crop (1976)

Water table depth	Plant population, stalks/ha			HSD_{01}	Sugarcane yield, t/ha			HSD_{01}	Theoretical sugar yield, kg/ha			HSD_{05}
	Flat	Bedded	Mean		Flat	Bedded	Mean		Flat	Bedded	Mean	
Constant (0.3 m)	99 100	85 500	92 300a[a]		88.1	75.1	81.6a		9910	8430	9170a	
Drained (1.5 m)	95 100	87 500	91 300a		87.4	77.6	82.5a		9270	8280	8780a	
Variable	86 500	77 800	82 200a		79.6	72.0	75.8a		9210	7910	8560a	
Mean	93 600b	83 600c		9400	85.0b	74.9c		9.9	9460b	8210c		980

[a] In a column or row, means followed by the same letter are not significantly different at the 1 or 5% level, as indicated, according to Tukey's HSD procedure.

and reduced yield more than a constant water table (Carter 1977). Therefore, caution must be exercised in discounting the probability of potential damage to flat-planted sugarcane based on these results, because the most adverse field and climatic conditions that can be expected were not included as a treatment in this study. Also, adequate surface and internal soil drainage should be ensured for any flat-planted sugarcane in Louisiana, although damage might be expected only for wet to moderately wet conditions.

CONCLUSIONS

Planting sugarcane on flat beds did not adversely affect sugarcane or sugar yields on Mhoon silty clay loam soil. Rainfall patterns during the 3-yr period of the study provided distinctly different soil water regimes varying from moderately dry to wet. Because the constant-water-table treatment was not the most adverse condition that could exist under field conditions, caution must be exercised in discounting the need for water table management for flat-planted sugarcane in Louisiana. During dry years, flat-planted sugarcane may actually produce higher yields than that planted on raised beds, as evidenced by the significant increase in yield obtained for flat-planted sugarcane during the dry year of this experiment.

A water-management system that has the capacity to maintain or control the water table over a range of depths between 0.3 and 1.5 m will increase sugarcane and sugar yield. The water table depth desired at a particular time will be determined primarily by rainfall. During a wet year, sugarcane and sugar yields for subsurface-drained treatments were significantly higher than those for high, constant-water-table, and variable-water-table (undrained) treatments. On the other hand, during a dry year, yields for the high, constant-water-table treatment were significantly higher than those for treatments for low (drained) or variable (undrained) water-table treatments. The high, constant water table provided a constant source of water readily available to sugarcane roots during drought periods.

REFERENCES

Carter, C. E., and J. M. Floyd. 1971. Effects of water table depth on sugarcane yields in Louisiana. Proc. Am. Soc. Sugar Cane Technol. 2(ns):5–7.

Carter, C. E., and J. M. Floyd. 1973. Subsurface drainage and irrigation for sugarcane. Trans. ASAE 16(2):279–281, 284.

Carter, C. E., and J. M. Floyd. 1975. Inhibition of sugarcane yields by high water table during dormant season. Proc. Am. Soc. Sugar Cane Technol. 4(ns):14–18.

Carter, C. E. 1977. Effect of water management on yield and longevity of sugarcane. Proc. Am. Soc. Sugar Cane Technol. 7(ns):27 (abstract).

Irvine, J. E., C. A. Richard, D. D. Garrison, W. A. Jackson, R. J. Matherne, C. R. Camp, and C. E. Carter. 1981. Sugarcane spacing: 3. Development of production techniques for narrow rows. Proc. 17th Congr., Int. Soc. Sugar Cane Technol. 1-11 February 1980, Manila, Philippines 1:368–376.

Legendre, B. L. 1976. An automated method for analyzing large numbers of sugarcane juice samples. Proc. Am. Soc. Sugar Cane Technol. 5(ns):71–75.

Matherne, R. J., R. D. Breaux, R. W. Millhollon, and R. D. Jackson. 1972. Culture of sugarcane for sugar production in the Mississippi Delta. Agric. Handbook 417. U.S. Dept. Agric., Agric. Res. Service, Washington, D.C.

Saveson, I. L. 1956. Flat planting of sugarcane on graded land. ARS 41–12, U.S. Dept. Agric., Agric. Res. Service, Washington, D.C.

Steel, R. G. D., and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill, New York. pp. 109–110.

Stubbs, W. C. 1895. Cultivation of sugar cane. D. G. Purse, Savannah, Ga. pp. 39–41.

Wasson, R. A., and E. R. McCrory. 1949. Louisiana sugarcane. Bull. No. 15, Louisiana Cooperative Extension Service, Louisiana State University, Baton Rouge, La.